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SPACE-BASED RADAR SIMULATION LABORATORY

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by

S.Y. Maskell

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DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 89-24

Canada

September 1989
Ottawa

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National Defence   Défense nationale

SPACE-BASED RADAR SIMULATION LABORATORY

by

S.Y. Maskell
Space-Based Radar Project Office
Electronics Division

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D6471

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ABSTRACT

The Defence Research Establishment Ottawa is developing a Space-Based Radar Simulation Laboratory. Initially, this Laboratory will consist of two simulators, an SBR System Simulator and an Integrated Surveillance and Interception Response System Simulator. This technical note describes both simulators and the expected capability of the Space-Based Radar Simulation Laboratory. Details on the development approach and on laboratory hardware are provided. A high level overview of the user operations for the two simulators is also given.

RESUMÉ

Le Centre de recherches pour la défense, Ottawa est en train de développer un laboratoire de simulation pour un Radar Spatial(RS). Initialement, ce laboratoire consistera de deux simulateurs, un simulateur d'un système RS et un simulateur pour un système de surveillance et d'interception intégrées. Cette note technique décrit les deux simulateurs et la capacité attendue d'un laboratoire de simulation pour un Radar Spatial. Les détails sur l'approche prise pour le développement et sur le hardware du laboratoire sont fournis. Un survol à un haut niveau des opérations qu'un usager devra effectuer est inclus pour les deux simulateurs.

EXECUTIVE SUMMARY

The Defence Research Establishment Ottawa is developing a Space-Based Radar Simulation Laboratory (SBRSL). Two simulators are being developed: an SBR System Simulator and an Integrated Surveillance and Interception Response System (ISIRS) Simulator. The development of the SBRSL has been broken down into two phases: the Definition Study Phase and the Detailed Design, Implementation, Test and Installation Phase.

The development work is now in the second phase. The contractors will be following the intent of DoD-STD-2167A. The two simulators are being designed and implemented using object-oriented techniques. Prototyping will be used for several aspects of the simulator.

The models that will be included in the simulators will initially be simple. It is anticipated that additional work will be carried out to later incorporate more detailed models.

The running of either simulator will consist of five basic operations:

- Simulation Configuration
- Run Planning
- Run Operations
- Data Analysis
- Data Output

The Simulation Laboratory will be used by researchers and contractors to study various design issues and modelling ideas for SBR.

TABLE OF CONTENTS

SPACE-BASED RADAR SIMULATION LABORATORY

1.0 INTRODUCTION

The Department of National Defence is funding a Space-Based Radar (SBR) research and development Project. Because of the complexity of a Space-Based Radar system and its operating environment, it is necessary to evaluate SBR performance through computer-based simulation. The Space-Based Radar Project is developing an SBR Simulation Laboratory (SBRSL). This Simulation Laboratory will be an essential research tool, particularly for system studies. For example, one such system study might look at the effect on target detection as the satellite altitude and the number of satellites in a constellation are varied. The SBR Simulation Laboratory will be a secure computing facility residing at Defence Research Establishment Ottawa (DREO). It will consist of hardware, a computing environment, and a number of software application programs. The Simulation Laboratory will be used for SBR research by SBR Project staff and private industry through contracts.

Two software application programs are under development. They are the SBR Integrated Surveillance and Interception Response System Simulator (ISIRS), and the SBR System Simulator. These simulators will evaluate an SBR system design when given a set of operating parameters, conditions or constraints. The SBRSL is not designed for real-time analysis or emulation.

These two simulators will be used to

- optimize parameters
- identify SBR system deficiencies
- evaluate SBR designs
- predict performance of SBR configurations

The SBR Simulation Laboratory is expected to be completed and ready for operation in mid-1990.

2.0 SIMULATORS UNDER DEVELOPMENT

Initially, the SBRSL will consist of two simulators: the SBR System Simulator and the ISIRS Simulator.

2.1 SBR SYSTEM SIMULATOR

The SBR System Simulator will simulate the SBR space and ground segments. This simulator will evaluate the performance of an SBR system operating independently of other surveillance sensors. The models in Table 1 will be included.

TABLE 1. SBR System Simulator Models

Space-Based Radar
- SBR ground segment
- SBR space segment
- SBR communications

Threats
- airborne targets
- ground jammers

Environment
- surface clutter
- update simulation time

The simulator will perform functional simulations in which the output is obtained as a table of values for one independent variable and several dependent variables. The independent variable could be time or some other

quantity. For example, a run could be submitted in which the scan angle varies from a minimum value of 20° to a maximum value of 40° in steps of 2°.

2.2 ISIRS SIMULATOR

The ISIRS Simulator will evaluate the performance of SBR working with existing and planned NORAD facilities. The models in Table 2 will be included.

Table 2. ISIRS Simulator Models

Command, Control and Communications
- Canada Sector Operations Control Centre (SOCC)

Surveillance
- ground-based radar
- space-based radar
- Airborne Warning and Control System (AWACS)
- high-level surveillance systems

Threats
- strategic bombers
- cruise missiles
- surface jammers
- civilian aircraft

Natural Environment

This simulator will perform stochastic, discrete-event simulations in which the output is obtained as timed event logs. An example of an event log is shown in Table 3. Results may be obtained through the repetition of runs in a Monte Carlo manner.

Table 3. Sample Event Log

Time	Source	Event
0:20:02	Strategic Bomber(1)	Change Course
0:23:34	SBR	Target Detect

3.0 DEVELOPMENT APPROACH

The development of the SBRSL has been broken down into two phases: the Definition Study Phase and the Detailed Design, Implementation, Test and Installation Phase.

3.1 DEFINITION STUDY PHASE

During the Definition Studies, the characteristics of the simulators were specified. User requirements were identified, software and hardware requirements were established, and the required simulator models and parameters were determined. Software development costs and hardware procurement costs were estimated and implementation plans were proposed. A set of experiments to be used in exercising the simulators were designed and described. In this phase, no software was developed and no hardware was purchased.

Two separate contracts were let to two companies to define the distinct simulators. These contracts were valued at $300,000 each. The contracts took one year to complete and finished in the spring of 1988. The ISIRS Simulator was defined by AASTRA Aerospace Inc. [1]. The SBR System Simulator was defined by Canadian Astronautics Limited (CAL) [2].

3.2 DETAILED DESIGN, IMPLEMENTATION, TEST AND INSTALLATION PHASE

The second phase in the development of the two simulators is the Detailed Design, Implementation, Test and Installation Phase. The objectives of this phase are as follows:

- define, specify and design the SBRSL and document all work
- specify the hardware requirements, procure, install and test the hardware
- implement the detailed design of both simulators
- test all software
- deliver a completed SBR Simulation Laboratory to DREO

One contract has been let for the second phase (Figure 1). The contracting team is as follows:

- AASTRA Aerospace - prime contractor
- Prior Data Sciences - software coding, Quality Assurance
- MPB - radar systems modelling
- GE-RCA - Air Defence Systems modelling

This contract started in January 1989, and is expected to be finished by mid-1990. The cost of the contract is $1,700,000.

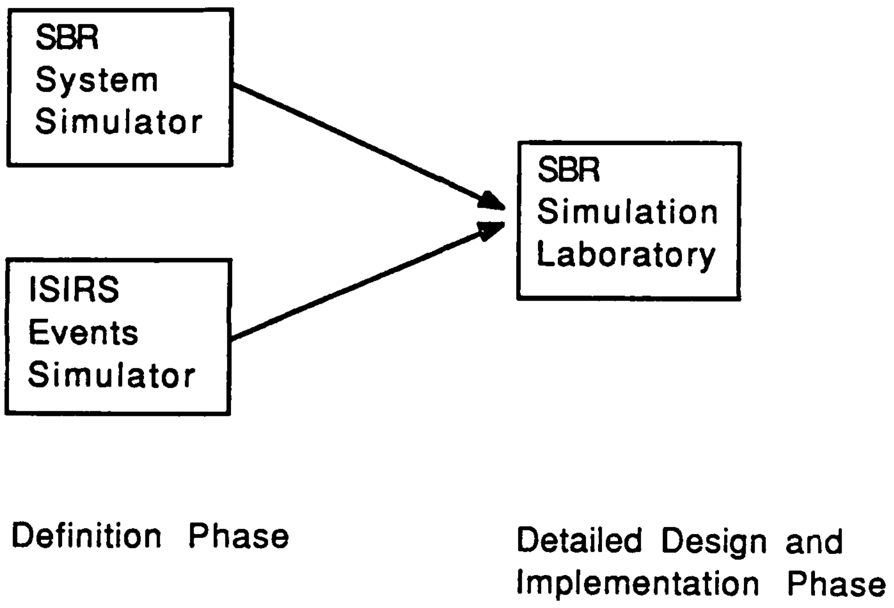

Figure 1. Development Strategy

3.3 SBRSL DEVELOPMENT STANDARDS

The Simulation Laboratory is being designed to allow future enhancements to the two simulators and to allow additional simulators to be incorporated into the Laboratory. To ensure this flexibility, a rigorous design and development approach is being enforced in the second phase contract. The contract team is following the intent of DoD-STD-2167A [3]. An Independent Verification and Validation contractor will be monitoring the entire development process.

3.4 SIMULATOR MODEL COMPLEXITY

Upon completion of the implementation contract, the SBRSL will consist of a set of models integrated in a software framework. This framework will allow for future software upgrades, enhancements, and additional simulators. The models being developed in this phase will be simple. This is being done to provide users with the capability to simulate a complete SBR System, although not at a detailed level. For example, the simulator will model radar performance using the radar equation. Detailed simulations of the processing of video signals will not be included. This capability could be added in the future, however, either by providing the necessary models for the SBR simulator, or by creating another simulator within the existing framework. It is anticipated that additional work will be carried out to incorporate more detailed models of various components. These upgrades will occur as the need arises.

3.5 DESIGN PHILOSOPHY

The two simulators are being designed and implemented using object-oriented techniques. A brief description of some object oriented terminology follows to provide insight into this design approach.

An object is a well-defined data structure linked with a set of operations that describes specifically how that data can be manipulated. Only these operations can manipulate the data. These operations are called methods. An object's data representation is hidden from the users. An object is requested to invoke one of its methods by sending it a message. This object is called the receiver. The message describes to the receiver object what operation is to be performed. The message may contain arguments to be passed to the operation. The message describes what operation is to occur, not how it will occur. This same message may be interpreted differently when sent to other objects.

Objects are grouped together into classes. The class provides all the information necessary to construct and use objects of a particular kind. Classes enable the management of collections of objects. A class can inherit methods from superclasses (those above it), and its methods can be inherited by subclasses (those below it). An example of classes is given in Figure 2. Sports car is a subclass of Automobile. Transportation is a superclass of Automobile and Aircraft. Automobile and Aircraft can inherit all the methods of Transportation [4][5].

The nature of the SBR and ISIRS simulators leads naturally to object oriented design. The various components can be well defined by objects and classes of objects. The models in the simulators are defined as a network of objects that interact via messages. This design philosophy will produce structured and modular simulators.

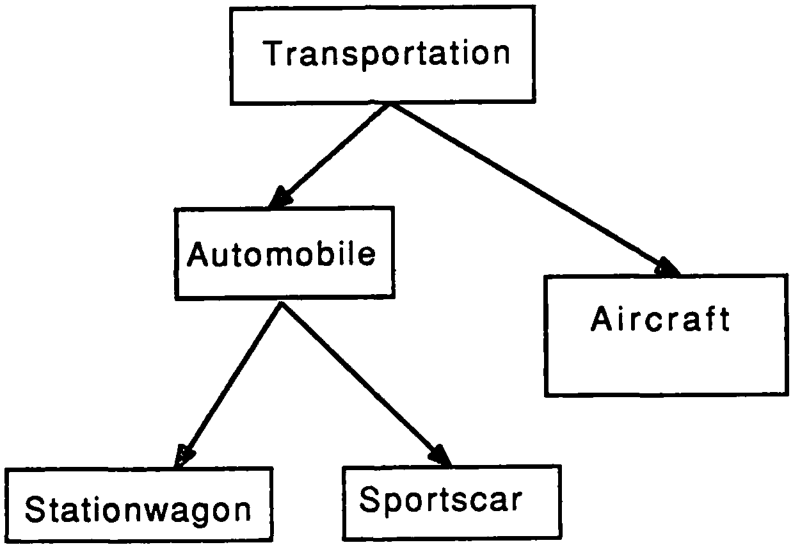

Figure 2. Example of Object Oriented Classes. Sports car is a subclass of Automobile. Transportation is a superclass of Automobile and Aircraft. Automobile and Aircraft can inherit all the methods of Transportation.

3.6 HARDWARE AND COMMERCIAL SOFTWARE PACKAGES

The hardware for the SBRSL consists of a SUN-4/260 compute server rated at 10 MIPS, with two SUN 4/110 diskless nodes rated at 7 MIPS each, all linked by an Ethernet network. The compute server has the following characteristics:

- 8 MBytes of RAM
- 688 MBytes of fixed disk storage
- a floating-point accelerator
- 60-MByte, 1/4-inch tape cartridge
- 19-inch colour monitor, resolution 1152 by 900 pixels

The diskless nodes each have

- a colour monitor identical to that of the server
- 8 MBytes of RAM
- a floating-point unit

The SBRSL hardware also consists of a Sun LaserWriter II and a Seiko CH5504-PM3 colour printer.

Databases and graphics software are not being designed specifically for the SBRSL as it is felt that this would be an inefficient use of manpower. Suitable commercial software packages are available. A database management system is necessary in the SBRSL because large amounts of data will be generated. It is imperative that there be a structured means of maintaining this information. The two simulators will provide the users with the capability to display graphics such as parameter barcharts and global maps.

The UNIX operating system will be used. The development language will be C++.

3.7 PROTOTYPING

Prototyping will be used for several aspects of the simulator. Prototyping is the process of developing a scaled-down version of a system to make the development of the full-scale system easier. The object-oriented approach being used in the design of the SBRSL will make the prototyping more flexible. The prototyping activity will be used to validate requirements. Should the requirements be changed after using the prototype, the change can be reflected in the prototype with less effort than would be required to change the full-scale software. The knowledge gained when designing the prototypes will be used to develop a more suitable SBRSL design than would otherwise be possible. One aspect of the SBRSL that will be prototyped is the user interface.

3.8 STRUCTURE OF THE STATEMENT OF WORK

The Statement of Work (SOW) breaks the second phase contract down into six tasks. This enables the work to be done in stages, allowing the SBR Project Office visibility and input into the development of each simulator. Each task is closely monitored to ensure that a useful SBRSL results. It is easier and less expensive to change a design while still in the requirements or preliminary design stages. It is much more costly and difficult to change a design at the implementation or test stages. The SOW was structured with this in mind. There will be major milestone meetings at the end of every task. The SOW consists of the following tasks:

Task 1 - Requirements Review and Implementation Plan

This task is broken down into the following subtasks:

- Review the work done in the Definition Study phase.
- Identify the requirements of the SBRSL.
- Provide an Implementation Plan.

Task 2 - Hardware Implementation

This task is broken down into the following subtasks:

- Review the hardware configurations proposed in the Definition Study phase.
- Recommend and justify a single hardware configuration.
- Purchase the hardware.

Task 3 - Detailed Specification and Design

The work in this task will create a detailed design of the two simulators that will initially make up the SBRSL.

Task 4 - Implementation of the Detailed Design

The work in this task will involve the coding of the detailed design.

Task 5 - Integration and Test of the Software

This task is broken down into the following subtasks:

- Integrate all software modules that were coded and tested in Task 4.
- Integrate all modules, testing each portion as it is included.

Task 6 - Acceptance Testing and Delivery of the SBRSL

Formal acceptance testing of the two simulators will occur in this task. As well, the contractor will deliver all hardware and software to DREO.

4.0 OVERVIEW OF THE SIMULATION LABORATORY DESIGN

The SBR System Simulator and the ISIRS Simulator have similar designs. The steps taken by the user to run either the SBR System Simulator or the ISIRS simulator will be the same. The running of each simulator is broken down into five basic operations:

- Simulation Configuration
- Run Planning
- Run Operations
- Data Analysis
- Data Output

The following descriptions of these operations provide some insight into the capability of the system.

4.1 SIMULATION CONFIGURATION

This operation will allow the user to define objects (models) and their parameters and messages. It also allows the user to specify which models will be combined to build the simulation configuration. It is not necessary to use all models listed in Tables 1 and 2 when building a simulation configuration. This allows the user the flexibility to create simple or complex configurations.

4.2 RUN PLANNING

This operation will provide the user with the ability to specify and manage the data to be used by the simulation run. This data will be organized into several datasets:

- initialization datasets - specify initial parameter values for the run
- recording datasets - specify the events and parameters that can be recorded during a run
- console datasets - specify the layout and content of displays used for monitoring interactive runs

4.3 RUN OPERATIONS

This operation will load models, initialize the simulation and start the run. As well, the user will be able to control the execution of batch and interactive simulation runs, and to examine the status of these runs.

4.4 DATA ANALYSIS

This operation will provide the user with the ability to analyze data recorded during runs and to correlate data collected from various runs. It also will provide the user with the capability to display data on the screen or to obtain a hard copy. It will be possible to load data into user-defined data tables and to store data in graphic metafiles. A metafile is a file that contains device-independent graphics instructions. The graphics stored on the metafile can be retrieved and displayed on any device. The user will be able to display plots, barcharts, tables and maps.

5.0 THE FUTURE OF THE SBR SIMULATION LABORATORY

The SBR Simulation Laboratory will consist of two simulators at the completion of the second phase of work. Future enhancements to these two simulators will be desirable to have more detailed models of SBR operations. As well, other simulators may be integrated into the SBRSL. For example, mechanical stability models, antenna simulation software, thermal deformation models, an IR simulator, and an EHF Satcom simulator are possible additions.

The SBRSL is seen as an evolving simulation laboratory. Researchers and contractors will study various design issues and modelling ideas for SBR covering a wide range of parameters and conditions.

It will provide confidence that the SBR concepts under consideration can meet the needs of DND, and that the R&D supported by the SBR Project will have beneficial effects on an operational SBR system.

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3. Department of Defense, DoD-STD-2167A, Defense System Software Development, 29 February 1988.

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LIST OF ACRONYMS

AWACS	Airborne Warning and Control System
CAL	Canadian Astronautics Limited
DREO	Defence Research Establishment Ottawa
ECCM	Electronic-Counter-Counter-Measures
IR	Infra-Red
ISIRS	Integrated Surveillance and Interception Response System
MIPS	Million Instructions Per Second
RAM	Random Access Memory
R&D	Research and Development
SBR	Space-Based Radar
SBRSL	Space-Based Radar Simulation Laboratory
SOCC	Sector Operations Control Centre
SOW	Statement of Work

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa Ottawa, Ontario K1A 0Z4	2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C or U) in parentheses after the title.)

Space-Based Radar Simulation Laboratory (U)

4. AUTHORS (Last name, first name, middle initial)

Maskell, Suzanne Y.

5. DATE OF PUBLICATION (month and year of publication of document) Sep 89	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 21	6b. NO. OF REFS (total cited in document) 5

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Note

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Space-Based Radar Project
Defence Research Establishment Ottawa
Ottawa, Ontario K1A 0Z4

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) D6471	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DREO TECHNICAL NOTE 89-24	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

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14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Space-Based Radar

Simulation

Object-Oriented

SBR

SBR System Simulator

Integrated Surveillance and Interception Response System Simulator